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Wood utilization in Aspen: Ecology and Management in the Western United States

E.M. Wengert

D.M. Donelly

D.C. Markstrom

H.E. Worth

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WOOD UTILIZATION

Eugene M. Wengert, Dennis M. Donnelly, Donald C. Markstrom, and Harold E. Worth

In the past, markets for quaking aspen timber from the Rocky Mountains have been insufficient to support significant harvesting. This shortage of markets severely restrained the potential for aspen management. As a result, many stands protected from wildfire gradually reverted to conifers (see the VEGETATIVE REGENERATION and FIRE chapters).

Significant markets for aspen products have not developed in the West because of a plentiful supply of coniferous woods and, to some extent, because the technical factors related to utilization of quaking aspen have not been well understood. Unfavorable economic factors, such as harvesting costs that are high relative to product values, also have inhibited aspen use. Resource managers and wood processors in the West have found it difficult to identify and evaluate viable utilization opportunities. A major barrier to utilization has been not knowing the volume and location of aspen available on a sustained yield basis.

To provide some of the needed information, this chapter examines aspen tree and wood characteristics, and products that can be made from quaking aspen. It also discusses the utilization outlook, and presents technical and economic requirements for beginning or changing to a wood products business featuring products made of aspen wood. The WOOD RESOURCE chapter presents supply and yield information for aspen in the West.

UTILIZATION CHARACTERISTICS

Each tree species has genetic and growth peculiarities that make it unique for utilization purposes. Some utilization characteristics of quaking aspen (*Populus tremuloides* Michx.) are very similar to other species, particularly to other *Populus* species. The technological and economic tasks of utilization are to mesh species characteristics as closely as possible with the properties desired in the end products.

The Tree

In the West, a typical aspen sawtimber tree, at maturity, is 80–100 years old, 60–80 feet (18–24 m) tall, and 11 inches (28 cm) d.b.h. or larger (Baker 1925). A few are older than over 200 years, taller than 100 feet (30 m), or larger than 20 inches (52 cm) d.b.h. One tree in Utah was reported to be 120 feet (36.6 m) tall and 4 feet (1.2 m) in diameter (Jones and Markstrom 1973).

The fungus *Phellinus tremulae* (= *Fomes igniarius*) frequently attacks the center of mature trees; fungal conks on the tree bole are its surficial evidence (Davidson et al. 1959) (see the DISEASES chapter). Defect deductions are typically up to 20% of the gross scale (Scribner Decimal C log rule) (Hinds and Wengert 1977). Aspen stems are often crooked or sweepy and may have numerous branches at mid-length. (See the MORPHOLOGY chapter for a discussion of general characteristics of aspen tree form.)

Published information on the characteristics of aspen trees and logs in the West is extremely scarce. Wengert sampled 282 logs—approximately every third tree-length log on 14 truckloads harvested from a southwestern Colorado timber sale.[1] These trees were considered to be fairly typical of sawtimber from pure aspen stands in the area. However, no statistically valid general inferences can be made from these data for the aspen resource in the Rocky Mountains. Measurements included log diameters at both ends (inside and outside the bark), log lengths, and gross and net scale (Scribner Decimal C log rule). Log taper averaged 0.114 inch per foot of length (0.97 cm/m). Scalable defect amounted to about 25% of the gross log scale, approximately one-half of which was attributable to crook and sweep. Bark volume averaged about 17% of the gross log volume, as contrasted with 12% reported for Minnesota aspen (Marden et al. 1975).

Relationships between gross merchantable volume of the tree, diameter at breast height, and its height were determined for aspen in Colorado (Edminster et al. 1982). These relationships can be expressed by the following equations—[1] for board feet and [2] for cubic feet:

$$V = 8 \text{ for } D^2H \text{ to } 2{,}500;$$
$$V = 0.011389D^2H - 20.5112 \text{ for } D^2H \text{ larger than } 2{,}500 \text{ to } 8{,}850;$$
$$V = 0.010344D^2H - 11.2615 \text{ for } D^2H \text{ larger than } 8{,}850. \qquad [1]$$

where:

V = gross volume, in board feet, inside bark Scribner Rule, merchantable stem excluding stump and top. Top diameter is 6 inches inside bark, and stump height is 1 foot.
D = d.b.h. outside bark, in inches.
H = total height, in feet.

[1]*Personal observations and field data collected by Eugene M. Wengert, formerly Research Wood Technologist at the USDA Forest Service, Forest Products Laboratory, Madison, Wisc., on assignment to the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

$$V = 0.002195D^2H - 0.9076 \text{ for } D^2H \text{ to } 11{,}800;$$
$$V = 0.001837D^2H + 3.3075 \text{ for } D^2H \text{ larger than } 11{,}800. \qquad [2]$$

where:

V = gross volume, in cubic feet, inside bark merchantable stem excluding stump and top. Top diameter is 4 inches inside bark, and stump height is 1 foot.
D = d.b.h. outside bark, in inches.
H = total height, in feet.

The Log

The size and geometry of trees and logs strongly influence utilization and the efficiency of converting timber into products. Product yield often can be greatly improved by selectively cutting tree-length logs into two or more short logs. This is particularly important for quaking aspen because of the high incidence of crook, sweep, and rot in typical mature trees. By judicious logmaking, straighter and less defective logs can be obtained from aspen boles that are crooked or contain rot. Generally, the shortest possible aspen logs produce the best yields of aspen lumber. Nominal 8-foot logs are the most common length used in Rocky Mountain sawmills. Also, this length is usually appropriate for pulpwood or veneering operations.

The Wood

The wood of quaking aspen in the West is classified as a "soft hardwood." It is virtually identical to the wood of quaking aspen and bigtooth aspen (*Populus grandidentata* Michx.) in the eastern U.S. and Canada. However, it differs substantially from the wood of most eastern hardwoods and from the woods of conifers, with which aspen is associated and processed in the West.

Anatomical Structure

The sapwood is whitish to creamy colored and generally merges into similarly colored heartwood without clear demarcation. Surfaces have a pronounced silky luster. The wood has a characteristic odor and taste only when green (Panshin and Zeeuw 1980). In addition, a condition called "wetwood," probably bacteria-caused (Ward 1976), often is present in aspen, and may be the source of the odor associated with green wood. Discolorations around knots and in the center of the tree are associated with wetwood or early stages of decay.

The darker color of the summerwood makes the growth rings in aspen distinguishable, but not conspicuous. The wood has numerous small pores (vessels) that are visible only with a hand lens on a cleanly cut cross-section. The pores are largest in the springwood and decrease gradually in size through the summerwood. The rays are so fine that they are scarcely visible, even with a hand lens. These anatomical characteristics of quaking aspen are indistinguishable from those of bigtooth aspen, and are similar to those of other *Populus* species, such as cottonwood. However, cottonwood is coarser in texture, somewhat darker in color (never creamy), and without luster.

The basic anatomical properties of aspen are unusual enough to make it a good choice for certain uses. For example, because properly dried aspen wood is practically without odor or splinters, food service manufacturers often supply containers and utensils made of aspen to avoid transmittal of odor from the wood.

Moisture Content and Shrinkage

The moisture content of wood in standing aspen trees varies considerably, depending upon the season and upon the presence of bacterial wetwood. No extensive study has been made of seasonal moisture content variation in aspen in the West. However, in the Lake States, Marden et al. (1975) found that the moisture content (as a percentage of ovendry weight) of 239 loads of freshly cut aspen pulpwood varied from 80% in summer to 111% in winter. In the Black Hills, Yerkes (1967) measured the seasonal change in 10 live aspen trees from an autumn low of 82% to a winter (February) high of 102%, which compares closely with the Lake States findings. The wetwood moisture content can be as high as 160% (Bois 1974, Knutson 1968). In summer, an average heartwood moisture content of 74% and sapwood moisture content of 91% were measured in the southwestern Colorado log sample described previously.[1] Bark moisture content is lower and less variable than that of wood (Marden et al. 1975).

Shrinkage characteristics are important for most wood products. Aspen has a fairly low green-to-ovendry shrinkage—3.5% radial, 6.7% tangential, and 11.5% volumetric (USDA Forest Service 1974b). The large tangential-to-radial ratio indicates that aspen will be subject to cupping and diamonding during the drying process, or during use if the moisture content changes significantly. Longitudinal shrinkage, which can be ignored for most species, is more significant for aspen. This unusually high longitudinal shrinkage results in lumber that has a tendency to bow, twist, and crook in drying and use, and veneer that may buckle if it is not properly dried.

Specific Gravity and Weight

Specific gravity is related to several wood properties and is frequently used as a relative measure of these properties within or between species. Specific gravity is an index of weight and density. It is based upon green volume and oven-dry weight.

The limited specific gravity measurements made for aspen in the West compare closely with data from Lake States and Canadian aspen. From the limited data available, it has been estimated that the specific gravity of quaking aspen in the West averages about 0.38, with a variation of about ± 0.08.[1] This specific gravity value is similar to the 0.367 value for Upper Michigan aspen (Erickson 1972) and to the 0.37 value for several sources of Canadian aspen (Kennedy 1965), but is slightly higher than the 0.35 value reported by the USDA Forest Service (1974b).

Specific gravity of bacterial wetwood is 0.03 to 0.04 lower than that of normal wood (Haygreen and Wong 1966, Kennedy 1974). The impacts of this difference on utilization have not been determined; but, factors such as pulp yield and wood strength, where the density of wood fibers is important, may be affected.

The specific gravity of aspen bark is higher than that of wood. Based on limited unpublished data for aspen in the West, bark specific gravity appears to average about 0.45, with a range of 0.38 to 0.57.[1] This compares with a range of 0.37 to 0.52 for Minnesota aspen bark (Lamb and Marden 1968), and 0.446 to 0.602 for aspen bark in Michigan (Erickson 1972).

Table 1 summarizes several weight, volume, and moisture characteristics of aspen in the West.[1]

Mechanical Properties

Aspen lumber sometimes is used for structural purposes, including aspen studs for light frame construction (Thompson 1972). Aspen 2x4's, produced in limited quantities in the Lake States, have been marketed under the grading rules of the Northern Hardwood and Pine Manufacturers Association. Design values for aspen used in light framing, as published by the National Forest Products Association, are listed in table 2. Aspen

Table 1.—Properties of wood and bark of quaking aspen in the West.[1]

	English	S.I. units
Specific gravity		
(Based on volume green; weight O.D.)[2]		
Wood	0.38	
Bark	0.45	
Density		
(Based on volume green)		
Wood (O.D.)[2]	24 lb/ft^3	0.38 g/cm^3
Bark (O.D.)[2]	28 lb/ft^3	0.45 g/cm^3
Wood at 12% water content	27 lb/ft^3	0.43 g/cm^3
Green sapwood	45 lb/ft^3	0.73 g/cm^3
Green heartwood[3]	41 lb/ft^3	0.66 g/cm^3
Green bark	55 lb/ft^3	0.88 g/cm^3
Moisture content (summer harvest)		
(Based on weight O.D.)[2]:		
Sapwood	91%	
Heartwood	74%	
Bark	96%	
Cord volume and weight		
Green wood per rough cord[4]	79 ft^3	2.2 m^3
Green wood per peeled cord[5]	94 ft^3	2.7 m^3
Green wood and bark per rough cord[4]	4,400 lbs	2,000 kg
Green wood and bark per rough cord assuming 33% bark loss in skidding[4]	4,100 lbs	1,900 kg
Lumber weight per MBF at 12% water content		
Thickness of 25/32 inch (1.98 cm)	1,800 lbs	800 kg
Bolt volume and weight[6]		
Green wood per bolt	4.9 ft^3	0.14 m^3
Green bark per bolt	0.79 ft^3	0.022 m^3
Wood (ovendry)[2] per bolt	117 lb	53 kg
Bark (ovendry)[2] per bolt	22 lb	10 kg
Green bark weight per bolt	44 lb	20 kg

[1]*Information based on personal observations and field data collected by Eugene M. Wengert, formerly Research Wood Technologist at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

[2]*O.D. = Ovendry; no further weight loss at 215°F (102°C).*

[3]*Wetwood may increase this value by 10% or more.*

[4]*Based on 16 rough bolts per cord.*

[5]*Based on 19 peeled bolts per cord.*

[6]*Based on bolt 100 inches (2.5 m) long and 10 inches (25 cm) diameter inside the bark at small end.*

Table 2.—Design values[1] (in pounds per square inch) for aspen lumber graded under Western Wood Products Association rules.[2]

Commercial grade	Size classification	Extreme fiber in bending "F_b" Single-member uses	Extreme fiber in bending "F_b" Repetitive member uses	Tension parallel to grain "F_t"	Horizontal shear "F_v"	Compression Perpendicular to grain "$F_{c\perp}$"	Compression Parallel to grain "F_c"	Modulus of elasticity "E"
Select structural		1,300	1,500	775	60	265	850	1,100,000
No. 1	2-4 inches	1,100	1,300	650	60	265	675	1,100,000
No. 2	thick	925	1,050	525	60	265	550	1,000,000
No. 3	2-4 inches	500	575	300	60	265	325	900,000
Appearance	wide	1,100	1,300	650	60	265	825	1,100,000
Stud		500	575	300	60	265	325	900,000
Construction	2-4 inches	650	750	400	60	265	625	900,000
Standard	thick	375	425	225	60	265	500	900,000
Utility	4 inches wide	175	200	100	60	265	325	900,000
Select structural		1,150	1,300	750	60	265	750	1,100,000
No. 1	2-4 inches	950	1,100	650	60	265	675	1,100,000
No. 2	thick	775	900	425	60	265	575	1,000,000
No. 3	5 inches	450	525	250	60	265	375	900,000
Appearance	and wider	950	1,100	650	60	265	825	1,100,000
Stud		450	525	250	60	265	375	900,000

[1] *These design values apply to lumber when used at a maximum moisture content of 19%.*

[2] *Source: Table 4A, Design Values for Wood Construction, Supplement to the 1982 Edition, National Design Specification for Wood Construction, National Forest Products Association, 1619 Massachusetts Ave. N.W., Washington, D.C., March 1982. 32 p. See Table 4A footnotes when using design values.*

[3] *Tabulated tension parallel to grain values for all species 5 inches and wider, 2-4 inches thick (and 2½-4 inches thick) size classifications apply to 5-inch and 6-inch widths only, for grades of Select Structural, No. 1, No. 2, No. 3, Appearance, and Stud (including dense grades). For lumber wider than 6 inches in these grades, the tabulated "F_t" values shall be multiplied by the following factors:*

Grade (2-4 inches thick, ≥5 inches wide) (2-4.5 inches thick, ≥5 inches wide) (Includes "Dense" grades)	Multiply tabulated "F_t" values by: 5-6 inches wide	8 inches wide	≥10 inches wide
Select Structural	1.00	0.90	0.80
No. 1, No. 2, No. 3, and Appearance	1.00	0.80	0.60
Stud	1.00	--	--

also has been used in the Rocky Mountains for mine timbers, where bending and resiliency are important considerations. In addition, there are many other uses and potential uses of aspen wood where mechanical properties are important, such as pallets or matchsticks.

Although there is little specific knowledge of the mechanical properties of aspen in the Rocky Mountains, it appears to be very similar to the wood of aspen from Lake States and Canadian sources. Therefore, some of the more important mechanical property values reported by various investigators for Lake States and Canadian aspen are summarized in table 3.

Aspen is roughly comparable to hardwoods such as basswood (*Tilia* spp.) and butternut (*Juglans cinerea* L.), ranking it at the low end of North American hardwoods in terms of strength. In relation to the softwoods, its mechanical properties are in the same general range as eastern white pine (*Pinus strobus* L.) and ponderosa pine (*Pinus ponderosa*), although there are major differences in some properties. Somewhat ironically, it is the modest level of aspen's mechanical properties that give it unique advantages in terms of utilization. It is strong enough to serve many functions adequately, and yet, is light in weight, which is sometimes an overriding consideration. Strength adequate for many purposes is combined with straight grain and freedom from splintering. Its soft texture permits the wood to be worked easily and provides an excellent surface for printing or painting. These properties make aspen especially attractive for crating and packaging lumber, matchsticks, and excelsior.

Fastener Withdrawal Resistance

The resistance of metal fasteners to withdrawal is strongly related to the density of the wood. Low density woods, such as aspen, do not perform as well as denser woods in applications where tight fasteners are important. Further, if nails are driven into green wood, they will lose withdrawal resistance as the wood dries. For example, a seven-penny cement-coated nail driven into the side grain of dry aspen should have a withdrawal resistance of about 194 pounds (88 kg). The same nail driven into green aspen that subsequently dries would retain a withdrawal resistance of only 20 pounds (9 kg) (Johnson 1947). Because the nail withdrawal resistance of aspen is comparatively low, more nails, larger diameter nails with large heads, or special withdrawal-resistant nails are required. However, aspen has little tendency to split when nailed, which partially compensates for its otherwise low nailholding properties.

Processing and Fabrication Characteristics

Machining.—Machining is a broad term that includes sawing, planing, shaping, sanding, and boring. Aspen can be machined easily; power consumption is low and tools dull slowly. However, it is difficult to obtain a clean and smooth surface on aspen unless special care is taken. Aspen's fibers sever less cleanly than most other woods; the tension wood common in aspen tends to leave a fine fuzz on machined surfaces. Also, from a limited number of planing observations, it appears that aspen wetwood seems to fuzz even more than non-wetwood.

Excellent turnings, borings, and planed or sanded surfaces can be obtained if the following conditions are maintained (Davis 1947, 1962; Stewart 1973a, 1973b):

1. Wood moisture content of 6% or less.
2. Knife angle of 25° to 30°.
3. A slow feed rate or lathe speed, maintaining at least 22 cuts per inch (8.7 cuts/cm) while planing.
4. A high cutter head speed, a peripheral speed above 5,000 feet per minute (25 m/s).
5. A shallow final cutting depth of approximately 1/32-inch (0.08 cm).
6. A slow axial feed speed when boring.
7. Avoid sanding with a very fine grit, because it increases fuzz.
8. Use special abrasives, antifuzz sealer, or a wash coat of sizing before final sanding. Fresh, sharp abrasives are required for preparation of good surfaces.

Table 3.—Specific gravity and mechanical properties of quaking aspen (*Populus tremuloides*).

	Kennedy (1965)	USDA Forest Service (1974b)	Kennedy (1965)	USDA Forest Service (1974b)	Haygreen and Wong (1966)	
					Wetwood	Sapwood
Specific gravity (SG)	[1]0.37	[1]0.35	[2]0.41	[2]0.38	[3]0.357	[3]0.393
Moisture content at test (%)	green	green	12	12	green	green
Static bending properties						
Stress at proportional[1] limit (psi)	2,900	--	5,200	--	2,666	3,406
Modulus of rupture (psi)	5,500	5,100	9,800	8,400	4,973	6,059
Modulus of elasticity (psi)	1,310,000	860,000	1,630,000	1,180,000	612,000	1,101,000
Work (inch lb/inch^3)						
To proportional limit	0.37	--	0.99	--	--	--
To maximum load	6.9	6.4	10.3	7.6	--	--
Total	20.2	--	21.0	--	--	--
Compression parallel to grain						
Stress at porportional limit	1,510	--	3,280	--	1,428	1,996
Maximum crushing stress	2,350	2,140	5,270	4,250	1,878	2,348
Modulus of elasticity (psi)	1,250,000	--	1,840,000	--	525,000	1,288,000
Compression perpendicular to grain						
Stress at proportional limit (psi)	200	180	510	370	--	--
Hardness (lbs)						
Side	320	300	480	350	--	--
End	340	--	630	--	--	--
Shear parallel to grain						
Maximum stress (psi)	720	660	980	850	--	--
Cleavage (lb/inch)	180	--	260	--	--	--
Tension perpendicular to grain						
Maximum stress (psi)	440	230	610	260	--	--

[1]*Based on ovendry weight and green volume.*
[2]*Based on ovendry weight and volume at 12% moisture content.*
[3]*Basis not specified; presumably ovendry weight and green volume.*

Drying.—Drying properties of wood are an important consideration in most forms of utilization. Aspen sapwood can be dried easily; but heartwood and wetwood are difficult to dry (Ward 1976). Sapwood usually is dried very rapidly. Kiln temperatures as high as 240°F (115°C), with a drying time of 36 hours, have been used successfully for 1-inch lumber. Because aspen has a high tangential-to-radial shrinkage ratio and an abundance of tension wood, both of which promote warping, proper stacking practices in air or kiln drying are needed to minimize the amount of warp (fig. 1) (Rasmussen 1961).

To reduce the effects of tension wood and casehardening, aspen should be conditioned at the end of drying with 180°F (82°C) dry-bulb temperature and a wet-bulb temperature determined from the wet-bulb depressions shown below. These are similar to those in Rasmussen (1961). Conditioning time for relief of stresses in 1-inch stock, although subject to wide variation, should be 6 to 12 hours.

Desired final moisture content	**Wet-bulb depression**	
(%)	°F	°C
5	14.0	7.8
6	12.0	6.7
7	10.0	5.6
8	8.0	4.4
9	7.0	3.9
10	5.5	3.1
11	4.5	2.5

Collapse is commonly associated with aspen wetwood, even sometimes during air-drying (Clausen and Kaufert 1952, Clausen et al. 1949). Ward (1976) found the kiln drying characteristics of aspen from Rocky Mountain and Wisconsin sources to be similar. Aspen wetwood from both sources invariably developed collapse, honeycomb, and/or ring failure during drying. Wetwood appears to occur mainly in established heartwood aspen in the Rocky Mountains, but also invades the innermost sapwood of Wisconsin trees (Ward 1976). Ward (1976) attributed the slower drying rate of wetwood to its higher moisture content and to the occlusion of vessels by bacterial slime. Normal aspen heartwood dries more slowly than normal sapwood because of tyloses in the vessels. Using a conventional kiln-drying schedule for 1 3/4-inch thick lumber, Ward (1976) found it took 90 hours to dry sapwood, 115 hours to dry heartwood, and 179 hours to dry wetwood.

Figure 1.—Drying of dimension lumber.

Slow drying of wetwood and heartwood is most noticeable in 2-inch and thicker stock. It is much less of a problem for 1-inch stock. Extending the air-drying period reduces kiln time and cost. Intermediate steaming during kiln-drying at high temperatures has been reported to be a suitable means of drying aspen studs (Mackay 1974). Rapid initial drying, followed by a long equalization period, is suitable when energy costs and kiln residence time are not critical. Where possible, aspen with wetwood should be segregated for special drying treatment.

The saw-dry-rip curing process developed by the USDA Forest Service has been used experimentally to dry aspen for studs with promising results (Maeglin 1979). In this process, logs are first sawed into 1 3/4-inch thick flitches; the flitches are kiln dried to 10% moisture content; then they are sawed and planed to produce 1 1/2-inch by 3 1/2-inch studs. This procedure eliminated much of the warping usually associated with aspen studs.

Preservative treatment.—Kaufert (1948) described decay resistance and preservative treatment of aspen. Aspen is very low in natural decay resistance. Untreated aspen posts or lumber in contact with soil may last only 2 years. Because of the low permeability of aspen wetwood and heartwood, it is somewhat difficult to get aspen to accept a uniform preservative treatment (Cooper 1976). Usually, small diameter logs consisting entirely of sapwood treat best.

Gluability.—Laboratory tests and experience have shown that aspen is generally easy to glue. However, because the wood is quite absorptive, rapid assembly may be required to avoid glue-starved joints. Additional water may be required to obtain suitable joints with some water-based adhesives.

Finishing.—Aspen is one of the best hardwoods for holding paint (USDA Forest Service 1974b, Zasada 1947). As with most woods, knots must be carefully primed. Aspen absorbs stains readily; but, uneven absorption can cause a blotchy appearance. A wash coat or application of a sealer before staining will alleviate this problem. As mentioned earlier, aspen also accepts inks very well for direct printing on the wood.

Pulping and fiberizing.—Quaking aspen has been extensively used for wood pulp in the Lake States and Canada (Auchter 1976, Keays et al. 1974). Almost 85% of the pulp mills in the Lake States use some aspen—a region where aspen makes up nearly 50% of total pulpwood production. Aspen is easily pulped using any of the following processes: groundwood, chemimechanical, semichemical, sulfite, and kraft. Aspen yields more pulp than softwood species or other hardwoods in all but the sulfite and kraft processes (Auchter 1976). In those processes, aspen's yield is only slightly less than spruce (*Picea* spp.) and hemlock (*Tsuga* spp.). The fiber characteristics of aspen make it particularly desirable for several types of pulp.

ASPEN PRODUCTS

The characteristics of aspen timber and wood make it quite suitable for some products. As noted previously, because of aspen's unique physical properties, it is a first choice for a few products. For other products, aspen's basic properties are technically acceptable; but, its choice over other woods would depend on availability and economics (see the Utilization Feasibility section in this chapter).

Pulp and Paper

Some of the advantages of aspen as a raw material for paper pulp were discussed previously. For example, groundwood paper of the highest printing quality is produced from aspen. In chemimechanical pulps, used mostly for hardboards and fiberboards, the low wood density of aspen is particularly advantageous in producing low and medium density boards. While aspen is suitable for the semichemical pulps used for both coarse and fine papers, the higher density hardwoods have a cost advantage. Aspen fibers provide special quality characteristics in kraft and sulfite pulps that make them suitable for fine papers. Because of aspen's low density, which makes it less attractive economically for chemical pulping, its future may be limited to groundwood and chemimechanical pulps (Auchter 1976). Blending aspen with a softwood to achieve desired characteristics in kraft pulps is a promising alternative (Hatton 1974).

Other important manufacturing factors are processing water, environmental concerns, technology that favors aspen use, and economic factors associated with harvesting the timber, such as topography, length of harvest season, and roads.

Other Fiber Products

Other fiber products that are technically feasible are panel products and animal feeds and bedding.

Among the panel products, hardboard (including medium density hardboard for house siding) and insulation board are the major consumers of wood fiber. Aspen fiber is well suited for these uses, although a high proportion of wetwood fiber may cause technical problems (Gertjejansen 1969). Markets are growing for a newer product—medium density fiberboard—which is used principally in the manufacture of furniture and cabinets. Aspen's properties make it a preferred raw material for this product, which requires a fine texture throughout to permit shaping and finishing panel edges without costly banding or filling.

The use of both the wood and bark of aspen for animal feeds has received considerable attention in recent years. Successful commercial use has been claimed by some cattle feeders. Aspen wood is about 35% digestible by ruminants and aspen bark, if properly supplemented, appears to be equivalent in nutrition to medium quality hay (Baker 1976) (see the FORAGE chapter). The digestibility of both wood and bark can be improved by physical and chemical treatments. In one feeding trial it was observed that pure aspen bark in pellets was not palatable to cattle.[2] Another study indicated that aspen bark was readily accepted in rations fed to sheep (Fritschel et al. 1976).

Particleboard

Products classified as particleboard have a wide range of properties. Two general types of particleboard are used in nonstructural applications. One type is used for under-flooring and other miscellaneous uses. The other is specifically designed for furniture and cabinet panels; it is usually employed as a solid core in plywoods, but sometimes as a base for grain-printing or opaque finishes.

Particleboards used for under-flooring are cheapest and least demanding of raw materials. Commonly, this inexpensive board is three-layered, with relatively fine particles on the surface and coarser particles in the center. Aspen can be mixed with softwoods and other hardwoods in particleboard (Gertjejansen et al. 1973, Stayton et al. 1971). Including aspen and other low density woods in the particleboard mix results in good bonding of particles at low pressures in the press (Geimer 1976). Therefore, low density (light) boards can be produced that are both strong and durable. Such boards are preferred in most nonstructural applications.

The same principles apply, but with more stringent requirements, for the type of particleboard used in furniture and cabinets. Smoothness, dimensional stability, machinability, and screw holding capability are more critical. Aspen particleboards of sufficient density can be produced to satisfy these requirements.

Aspen is an excellent raw material for both types of particleboard. It has been widely used in the Lake States and Canada for these products, either alone or in mixtures. Residues from sawmills and planing mills have been the preferred and most used raw materials for particleboard.

[2] *Fullinwider, J. A. 1976. Colorado steers and aspen bark. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, State and Private Forestry. 20 p. [Processed report]*

Structural Flakeboard

The newest panel product to achieve international significance is structural flakeboard (Koch and Springate 1983). It is a specialized form of particleboard sometimes called "waferboard" or "oriented strand board." Structural flakeboard can substitute for sheathing-type plywood used in frame construction (fig. 2). Flakeboard differs from conventional particleboard in that the wood elements are thin, parallel-cut flakes of uniform thickness and size, bonded in an alignment analogous to the veneers in plywood.

The particles in waferboard are approximately as wide as they are long, and are bonded parallel to the plane of the panel. The grain direction of individual wafers is random. In oriented strand board, the flakes are longer than they are wide, and alternate layers are perpendicular to each other in a cross-plied arrangement. This is in contrast to the random orientation of the smaller particles in conventional particleboard. With careful alignment of flakes, the strength and dimensional stability of flakeboard is significantly better than particleboard.

Aspen is an excellent raw material for structural flakeboard. While other species have been used, approximately 95% of the structural flakeboard recently produced in Canada and the United States has been made from aspen. Aspen's unique combination of properties including low density, freedom from resinous extractives, and straight grain, make it nearly ideal for this use.

Figure 2.—Structural flakeboard manufactured from aspen.

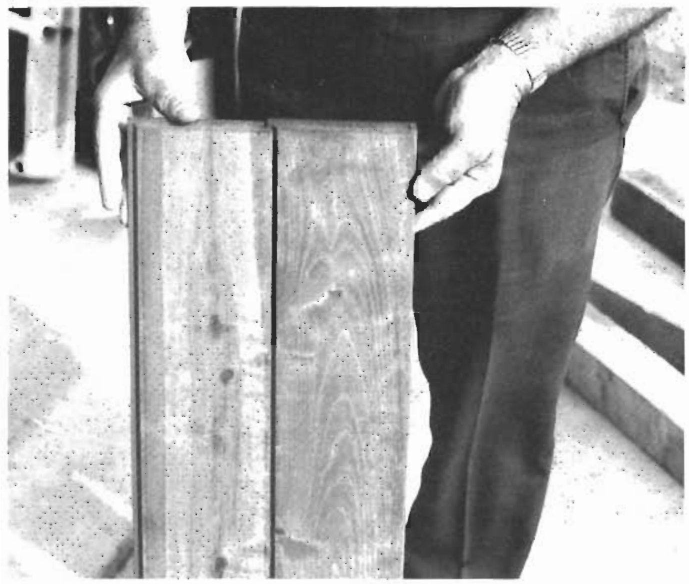

Figure 3.—Stained decorative interior paneling manufactured from dimension lumber.

Sawn Products

Boards, dimension lumber, and timbers all have been produced from aspen in the West. This lumber has been used for a variety of secondary products, ranging from pallets and shipping containers to decorative interior paneling. In the Rocky Mountains, most aspen logs have been processed by sawmills that produce mostly softwood lumber (fig. 3).

In the West, aspen trees that appear to meet sawtimber requirements when standing often prove to be culls when felled. They often have large amounts of heart rot. Lumber grade yield and value of aspen logs processed in New Mexico and Utah were highly variable and could not be accurately predicted by conventional tree or log grading methods (Wengert and Donnelly 1980). Noreen and Hughes (1968) reported recovery of lumber and other products from aspen in Minnesota.

Lumbermaking residues include not only sawdust, planer shavings, slabs, edgings, and trim, but also defective logs or parts of logs, and lumber that does not meet size or grade requirements. Bowyer's (1974) analysis of several forms of integration of aspen production in Minnesota provides a methodology that may be useful to prospective producers in the West.

The small volume of aspen sawed in the interior West has been used in numerous ways. End uses include pallets, paneling, boxes and crates, mine posts, toys, furniture, and construction framing.

UTILIZATION OUTLOOK

Harvesting Opportunities

Pure even-aged stands of mature aspen trees, on flat benches or gentle slopes are the most favorable for harvesting (fig. 4). In these stands, clearcutting is both the best and least costly silvicultural treatment.

Harvesting potential decreases as aspen becomes more intermixed with conifers or grows on steeper slopes. In these instances, aspen harvesting is expensive and may severely damage residual conifers. Many situations exist between these extremes. Uneven-aged stands may have a higher incidence of rot, with consequent lower product yields (Betters and Woods 1981).

Many aspen stands have low volumes of harvestable timber per acre. The high unit cost of harvesting such stands often has prevented their utilization for low-priced products. Combining aspen and contiguous softwood harvesting has been used to reduce costs. Developing efficient harvesting systems, specifically suited to aspen, may be another approach (see the HARVESTING chapter). Size, age, and disease are primary factors in the utilization of aspen. As is true of all timber, it is more economical to process larger trees. Approximately two-thirds of the aspen sawtimber in the Rocky Mountains is 11–15 inches (28–38 cm) in diameter, and 99% is smaller than 23 inches (59 cm). However, when aspen trees reach a diameter of 12 inches (30 cm) or more (typically in 80–100 years), heart rot becomes increasingly prevalent, reducing the net volume of wood in the stand (Davidson et al. 1959, Hinds and Wengert 1977). A sound 20-inch (51 cm) diameter aspen tree is a rarity. Not only does decay cause an appreciable loss of wood, but it also increases harvesting and processing costs per unit of product. To avoid this problem, aspen either must be harvested at a size and age before decay becomes extensive, or utilized for products that are tolerant of unsound wood. One study of logs from a limited area found aspen utilization also was limited by its high yields of low lumber grades, caused primarily by knots and log crookedness (Wengert and Donnelly 1980).

Figure 4.—Aspen logs being skidded with a crawler tractor.

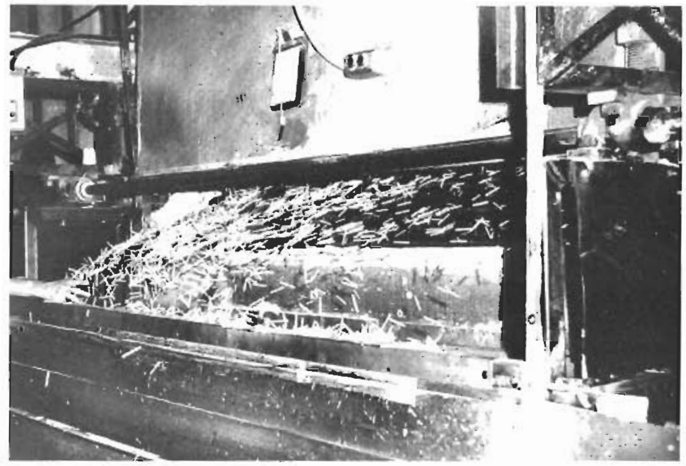

Figure 5.—Manufacture of matchsticks from aspen in the West.

Utilization History

Aspen has a long history of utilization in the West. Baker (1925) reported local use of aspen in Utah for mine props, posts, poles, bridge planking, flooring, and fuelwood. He also reported that early Mormon pioneers made furniture from aspen. Lumber traditionally has been the most common product, usually produced by sawmills that also produce softwood lumber. Other products made from aspen include excelsior, match splints (fig. 5), wall paneling, mine timbers, furniture, roof and siding shakes, pallets, paper pulp, toys, shipping containers, animal (mink) bedding, and beehives.

Site and stand characteristics, and multiple use management decisions have restricted utilization of aspen in the interior West to less than 10 million board feet annually. Typically, most aspen has been harvested in stands mixed with conifers, and has been processed nearby. For sawmills, aspen has been only a small percentage of processors' raw material.

Current and Potential Utilization

Potentially, up to 60 million board feet of aspen per year could be harvested in the interior West on a sustained yield basis (see the WOOD RESOURCE chapter). However, establishment of a major lumber industry based on aspen may not be practical because of aspen's characteristics (small size, high cull, etc.), its inaccessibility, and the high harvesting and transportation costs common throughout the Rocky Mountains.

Despite this, some use of aspen in the Rocky Mountains in the near future probably will continue to be for lumber, lumber products (especially pallets), and excelsior. In addition, use of small amounts for matches and paneling also is likely to continue. If subsurface mining increases in the region, additional markets may develop for aspen mine timbers.

However, aspen in the West currently has greatest potential for particleboards and other fiber products. There has been a rapidly growing interest and market throughout the continent for manufactured composition boards made from aspen flakes. Aspen's suitability for fiberboards and other fiber products makes utilization opportunities promising. Success in these areas would depend largely on the feasibility of concentrating large volumes of aspen roundwood or suitable residues at the processing sites (see the Utilization Feasibility section in this chapter).

Two large plants manufacturing aspen waferboard currently operate in central Colorado. Raw material for these operations is harvested from pure aspen stands. Regardless of the effects of economic cycles on composition board manufacturing, aspen in pure stands is an attractive resource whenever large amounts of aspen fiber must be produced efficiently.

The increased demand for fuelwood has drawn on the aspen supply as well as other species, mostly in the form of dead trees. Harvesting live trees for fuel is becoming more common. If demand continues to increase, future aspen utilization could be largely for fuelwood. Assuming 85 cubic feet of solid wood in a cord of aspen and a moisture content of 20%, the total heating value of the cord would be about 14.7 million BTUs (Milton 1980). At a typical heating efficiency of 55%, the cord of aspen would deliver usable energy of approximately 8.1 million BTU's. This is equivalent roughly to 88 gallons of No. 2 fuel oil at 65% heating efficiency.

One additional use for large amounts of aspen fiber is in paper pulp. While no outlet for aspen pulp is likely soon in the interior West, population expansion in the region could lead to greater production of pulp and paper.

UTILIZATION FEASIBILITY

In addition to technical considerations, several other categories of information need to be examined when considering the possibilities of a business based on the aspen resource. These include information about the aspen forest resource relevant to a particular kind and location of business; information about the product needs and markets that may be served from that location; information about possible production facilities; and analysis of the economic framework that ties together the wood resource, the production facilities, and the product markets.

Elements from each category affect elements elsewhere in an analysis in a highly interactive fashion. Consequently, when performing an analysis based on the ideas following, several iterations are likely.

The Aspen Resource

Some key considerations about the forest resource include: (1) location of aspen stands; (2) species composition of stands classified as aspen; (3) diameter and height distribution, by species, of aspen stands; (4) defect type and proportion (if any) found in the aspen stands; (5) topographical characteristics, including slope and aspect, of aspen stands; (6) soil type; (7) distance from potential manufacturing locations to aspen stands, by road surface type, steepness, and curvature; and (8) administrative requirements of owners or managers of the timberlands.

Anyone considering starting a business based on a particular species of wood, such as aspen, probably has decided on a product idea and has some idea of the scale of enterprise. The next step is to determine how much harvestable aspen is within various distances from the business location, in order to decide whether enough raw material required for the level of production planned exists within a reasonable distance to support the business.

As noted elsewhere in this book, aspen often grows with other species. Up to the point where other species exceed some volume limit, such stands are classed as aspen. However, the timber buyer may have to cut non-aspen species also, to fulfill harvesting or management requirements.

The planned product implies how much attention should be given to diameter and height distributions, by species within aspen stands. Without sufficient inspection, stands may subsequently prove to be too small in acreage, consist of trees poor in quality, or have trees that are too small to be profitably harvested. For a sawn product, diameter and height of trees govern product recovery percentages to a great degree and also may influence quality. For fiber or chip products, such as pulp, flakeboard, or animal bedding, diameter and height are not quite as critical but still determine how many pieces must be handled to get a unit of product. Even for firewood, diameter and height influence the volume of solid wood and the methods that are feasible to handle trees and logs.

The average diameter of quaking aspen logs typically is smaller than most other western sawtimber species. This affects not only the technology used in handling and product manufacturing, but also cost. To some extent, it also limits the timber products that can be made from aspen. For example, in the West, aspen lumber typically is produced in mills that primarily process softwood logs. Because much of the softwood timber processed in the Rocky Mountains is also of relatively small average diameter (fig. 6), sawmills tend to be of the small-log type. Therefore, sawing softwoods and small amounts of aspen in the same mill usually is compatible.

For some products, such as firewood, defects may be tolerable. Conks or tree form, for example, probably make no difference. However, rot, if prevalent in the stand, would diminish firewood recovery. For manufactured products, most kinds of biological (conks, rots, etc.)

or physical (fork, sweep, etc.) defects are undesirable. Whether or not such defects make an enterprise based on aspen uneconomical depends on the extent and severity of defects. Conversely, some specialty products might actually take advantage of defects such as wood grain swirls.

Aspen sometimes grows on slopes too steep or soils too unstable to permit harvesting. Topographical characteristics, along with soil type, determine how easily harvesters can work in the aspen stand and whether the forest environment needs protection with special measures. Slope obviously affects size and type of harvesting equipment. Soil type governs, along with slope, the practicality of the kind of harvesting and when and how soon equipment can be moved onto the site. Aspect, or direction of the slope, is an indicator of duration and intensity of drying sunlight.

The aspen stand location is defined by more information than just overall distance from a manufacturing location. An analysis of harvesting feasibility should look also at the distances to be traveled on various types of road surfaces. Many aspen stands may be inaccessible—too far from existing usable roads to permit economical logging. Further complexities are the distances traveled on roads of varying steepness and curvature. All of these elements significantly affect the cost of raw material transportation from woods to mill.

Finally, various administrative requirements of the owner or manager may be connected with an aspen stand. Such requirements may be based on environmental considerations, on the preferences of the owner, or on existing laws or regulations. For example, benefits from recreation, wildlife, scenic beauty, or watershed protection may be incompatible with harvesting. In total, these items could affect how logs or raw materials are cut, skidded, and transported.

Product Use and Markets

A thorough analysis of how the proposed product will be used, and in what markets the product can compete is important. Rich (1970) provided a detailed examination of forest product markets. In addition, a general text that covers the basics of marketing also can help (e.g., Stanton 1978).

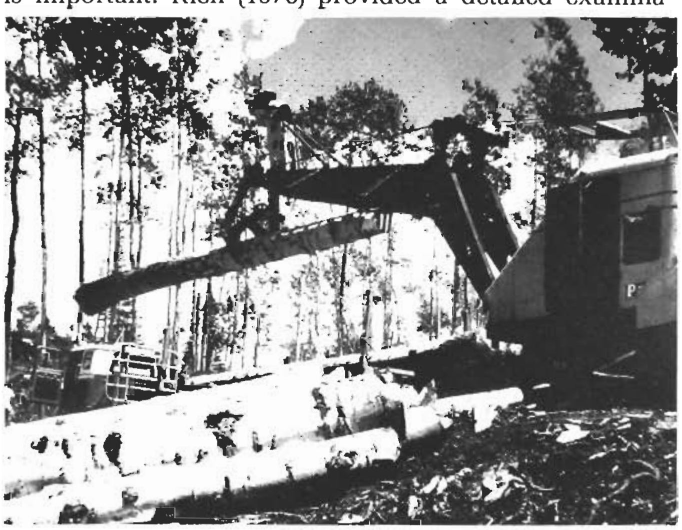

Figure 6.—Aspen sawlogs being loaded onto a log truck.

One of the first major decisions, if aspen is harvested along with other species, is whether to market aspen products alone or to market them together with the same product or a different product from the associated species. For example, if rough, unfinished timber is to be sawn for a local market, perhaps no differentiation of species is needed. However, if quality aspen paneling is to be manufactured, then non-aspen logs must be sold or manufactured into another product.

What product to market depends, in part, on the interests and experience of the entrepreneur. It also depends on whether the product is classed as a commodity or a specialty. Commodities, such as dimension lumber are hard to distinguish (product differentiation); in this case, successful marketing may depend on price and service, rather than on demand for the specific product. For example, one unusual use of aspen, although still as a commodity product, is as a component of animal feeds. In this situation, marketing appears to depend upon the availability of preferred roughages, such as hay. For feeder operations in hay-short areas, but close to aspen sources, aspen may offer a viable alternative. Specialty items, in contrast, may be highly differentiated as products and in specific demand. The nature of the specialty product is such that few other competitive products exist; therefore, price and service are co-equal, or perhaps secondary to the satisfaction of the consumer. Donnelly et al. (1983) discussed how these marketing factors and others interact for forest products in the Rocky Mountain states.

The main point of marketing is to provide customers with a salable combination of product and service. If the product is an undifferentiated commodity, relatively small changes in price likely will cause large changes in demand for the product, as well as demand for the commodity in general. For example if transport costs to a distant market area increase moderately, forcing prices up, customers may stop buying one seller's product in favor of a cheaper, competitor's product. If, in contrast, the product is a differentiated specialty, very much in demand, with few substitutes, then relatively large price changes may have little effect on demand. Some of the factors to be included in a market study are the target consumer profile, location and spatial distribution of target consumers, product line and product mix, pricing policy, channels of distribution, and promotion and selling of the product.

Production Facilities

This chapter cannot examine the specific types of aspen product manufacturing facilities. They range from multimillion dollar, highly engineered facilities, such as particleboard plants, to inexpensive homemade operations, such as tractor powered, belt driven portable sawmills. However, there is common information applicable to all facilities that an operator should consider.

One important basic consideration is the physical flow of material through the manufacturing process. The time-based rate of transformation of raw material affects the cost of the final product. The prospective wood products manufacturer should diagram the flow of the operation in some detail and estimate the rate of flow and the product recovery at each step. The faster the flow and the less waste there is at each step, the greater the likelihood is of a profitable operation.

For every product there probably is a range of fixed and variable costs that are determined by how production facilities are configured. For example, all new, undepreciated equipment has high fixed costs relative to used equipment. Conversely, used equipment may have low fixed costs but also may have high variable costs of repair and maintenance. The choice may depend on ability to maintain equipment and personal expectations about reliability. Production facilities for some products require more capital than for others. Because fixed costs must be spread over more units to lower the unit price, product volume goals depend on the structure of types of costs. Product volume is also highly interrelated with availability of raw material and the marketing facilities available.

One important aspect of any production facility is the accumulation, storage, and marketing of by-products. Typically, sawmills produce cull logs and log pieces, slabs, edgings, chips, planer shavings, and sawdust. Almost all wood products operations have some type of residue. Two means of reducing residue are to burn it for heat or power, or to sell it to someone else for raw material. For example, the availability of residues from other wood processing industries, such as sawmills, is an important factor affecting pulp production.

Conversely, a planned product may depend on raw material obtained as residue or from harvest. Examples of such products are particleboard, flakeboard, pulp, or fuel. One uncertainty is residue availability. When lumber production from aspen is limited, for example, aspen residues from sawmills and planing mills are not readily available, even in the Lake States. Harvesting aspen specifically for manufacturing particleboard is an alternative; but this may double the cost of raw materials. However, for flakeboard manufacture, roundwood is preferred to sawmill residues; therefore, for this product, aspen is not as economically disadvantageous as it may be for conventional particleboard production.

Economic Analysis

Information about physical product flow and financial cash flow are essential elements that integrate considerations about raw material, marketing, and production. As noted previously, business analysis is likely to be an iterative process with each successive step answering further questions and becoming more complex. At each step, list the major uncertainties associated with the information.

For example, starting with the market, because it is basic to other considerations, first determine how many units of product can be sold at what price. How certain are the figures for each price and volume level? What is the nature of competing products and of competitors? Make a list of all the various possibilities that are likely. Pick two or three that are most likely to use for further consideration.

Given the volume requirements in the market estimates, what kind of production facilities are required to satisfy each of the most likely estimates? Is the range of volume estimates small enough that one plant configuration with slight modification could service the likely range? Or does the volume range imply that radically different plan scales must be considered? These possibilities are examples of uncertainty in the market place feeding back to affect vital decisions in production.

Each marketing scenario, and its corresponding production facility, implies a supply of raw material sufficient to support the operation. What is the range of raw material volume? How likely is it that each level of raw material volume can be obtained? Again list locations and uncertainties.

If, at this point, a decision is made to continue, the next step is to assign costs to all the steps of the preceding iteration. Again, cost estimates are likely to vary and have various levels of certainty. In addition, costs also vary over time, usually increasing; therefore, consider further analysis with higher costs. The result of this analysis should be a range of break-even costs with some idea of the certainty associated with them. How do these cost ranges compare to the price ranges discovered during the marketing research?

At this point, there may be many more questions. In addition to the sources that provided information up to this point, others include USDA Forest Service and state forestry offices, and appropriate publications (e.g., Donnelly and Worth 1981, Kallio and Dickerhoof 1979, Lawson 1972, Markstrom and Worth 1981.